now of Johns Hopkins University, as well as by Dr. William L. Wardwell, as sarcoma. It was found impossible to remove the entire growth, and the wound made was tamponed and the operation abandoned. Arsenous acid was subsequently injected into isolated areas in the remaining portion of the growth with the view of obtaining some specific action from this agent. Before all portions of the growth had been subjected to this treatment a violent suppurative inflammatory action occurred, and the treatment was abandoned. No hope was entertained of his recovery. The process of suppuration continued for several weeks, when it gradually ceased, the tumor finally disappearing. Ten years afterward he was known to be free from a recurrence of the disease. In commenting upon the case, Dr. Wyeth states that there was no erysipelas present, and that the case was positively one of sarcoma cured by the action of other septic or toxic agents of inflammation.

THE RÖNTGEN RAYS IN OPHTHALMIC SURGERY.

By William M. Sweet, M.D.,
PHILADELPHIA.

The value of the Röntgen rays as a means of determining the presence of pieces of metal in the eyeball has been conclusively shown by the experiments of a number of investigators, the earliest workers in this field being Dr. Clark, of Columbus, Dr. Williams, of Boston, and Dr. Max J. Stern, of this city. The knowledge that a foreign body is in the eye, however, is not all the information required by the surgeon who operates with the electro-magnet for its removal. Without some indication of the position of the body, it is not possible to reduce the percentage of failures of the magnet operation. The ordinary radiograph does not accurately indicate the position of the shadow of the foreign body on the plate in relation to the shadows of the bones of the head. Hence, it is desirable to state the exact spot at which to insert the magnet with the least injury to the structures of the eye.

The first attempt to determine the approximate location of foreign bodies in the eye by means of metal indicators placed without the ball was made by Dr. H. Lewkowitch, and reported in the London *Lancet* for August 15, 1896. In these experiments, which were made upon sheeps' eyes and the doctor's own eyes, the indicator consisted of a piece of wire placed in front of the eye, one of the arms of the apparatus pointing to the centre of the cornea. Only the anterior portion of the eyeball was included in the radiograph, the eye being rotated inward or outward to include a larger part of the globe. The determination of the position of the foreign body was then made by a triangulation of two shadows on the plate cast by the foreign body, by moving the tube a known distance from the first position in making the second exposure. The photographic plate was placed at the inner canthus. In addition to these complications, and the liability of error in determining the angles of the tube in its two positions with the plate and the foreign body, the method is open to the objection that only a small portion of the eyeball is included in the radiograph.

In my early experiments with pigs' eyes placed in the ordinary Viennese mask, it was found that unless the rays were passed through some portion of the bony walls of the orbit, foreign bodies in the posterior portion of the vitreous chamber could not be shown.

In the first experiments which I made upon the human subject the photographic plate was inserted at the inner canthus. Photographic films were used, as being more readily cut to the shape desired. Each plate-holder carried two films, and two negatives were thereby secured at each exposure, thus avoiding errors arising from imperfections in the film coating.

The indicating apparatus consisted of an aluminum frame carrying three steel rods, each with a rounded end. The rounded extremities were adjusted to the inner and outer canthus and to the eyeball at the centre of the upper lid. Two exposures were made, one with the Crookes tube on a line with the inner and outer indicators, and the other below the horizontal plane of these indicators. In determining the position of the foreign body in the eye, the apparatus was attached to a fixed support, and a lighted candle employed to cast the shadows of the indicators on a cardboard similarly to those made on the negatives by the x-rays. A small object was then held in such a position that its shadow was identical to that of the foreign body. The candle was moved until the shadows of the indicators corresponded to those on the second negative. The crossing of the two lines of shadow of the test-object represented the situation of the foreign body.

This method of marking was first employed in the case of a young man with a piece of steel in the lens, sent to me by Dr. A. G. Thomson. From a number of negatives I located the body 7 mm. behind the centre of the cornea, and about a millimetre to the nasal side. Dr. William Thomson subsequently removed the soft and opaque lens with the piece of steel imbedded in it.

While the use of the photographic plate at the inner canthus has the advantage of bringing the sensitive film much closer to the eyeball than when in any other position, an important consideration when dealing with very small objects, it has the objection that the whole eyeball is not included on the plate. For this reason, and also because of the imperfect coating of the celluloid films, I have since used glass plates bandaged to the temple. Instead of three indicators, two only are now used.

The principle of employing two objects of known position to locate the situation of a third object from the shadows cast by these objects upon a flat surface is extremely simple. For all practical purposes we may regard the rays from a Crookes tube, at least thirteen inches away, as being parallel in passing through a body so small as the eye. Therefore, if the relative position of two objects is known, we can readily determine the situation of the third. In employing this principle in locating foreign bodies in the eye, three factors are of importance, namely:

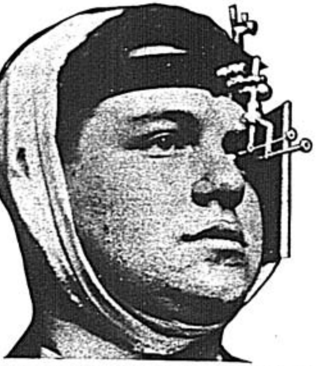
That the two indicating objects shall be at a known distance apart, and shall be parallel to each other and to the plate, and also in a perpendicular line with the plate.

That one object shall point to the centre of the cornea and be at a known distance from the eyeball; and

That the visual axis shall be parallel to the indicators and to the plate.

With the above facts known, it is unnecessary to take a measurement of the angle of the tube with the plate, as this is readily determined from the negative. The two indicators being parallel to each other and to the plate, the distance the shadow of one of the balls is posterior to that of the other is the measure of the distance the source of the x-rays is carried to the front.

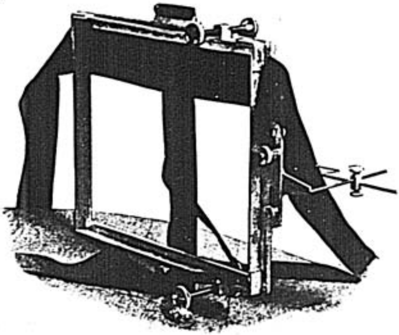
FIG. 1.



Indicating apparatus supported by head-band and plate held in place by bandage.

The indicators may be supported by a head-band and the plate held in place by an ordinary bandage, although more accurate results are obtained by employing a special form of apparatus, in which the indicators are attached to the plate-holder, and are at all times parallel to each other and to the plate. The indicators are adjustable, so that one may be placed opposite the centre of the cornea while the other is toward the outer canthus.

FIG. 2.



Indicating apparatus and plate-holder combined.

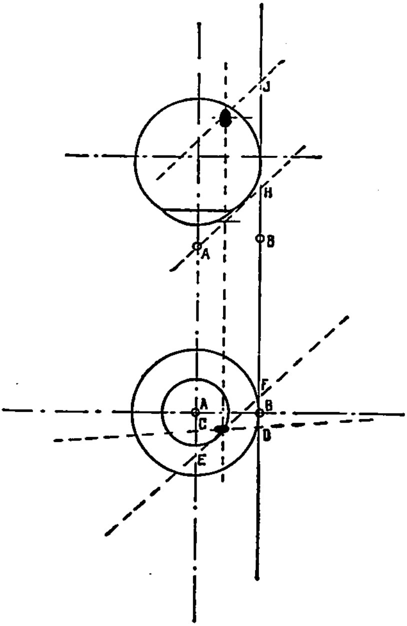
In making the negatives the tube is in front, about thirteen inches from the plate and at an angle of from fifteen to forty degrees with a vertical plane passing through the apex of each cornea. The plate is to the opposite side of the head, and the rays pass through the eyeball and the external orbital wall before reaching the sensitive film. Two exposures are made, one with the tube in a horizontal plane with the two indicators, and the second at any distance below. The angle of the tube below the horizontal is unimportant as long as the two exposures give different relations of the indicators on the negatives.

In determining the position of the foreign body in the eye, two circles 24 mm. in diameter (equivalent to the size of the globe) are drawn upon paper. One circle represents a horizontal section of the eyeball, and the other a vertical section. Upon the vertical section a spot is made at the centre of the circle, indicating the position of the central indicator of the apparatus. The distance between the two indicators is measured toward the temporal side, and a spot made to show the position of the external indicator.

On the circle representing a horizontal section of the eyeball a spot is made anterior to the centre of the cornea and at the same distance that the centre indicator was from the eye when the radiograph was made. Another spot to the temporal side, measured by the distance between the two balls of the apparatus, marks the situation of the external indicator.

By taking the first negative with the tube horizontal to the two indicators, we measure the distance of the foreign body above or below the

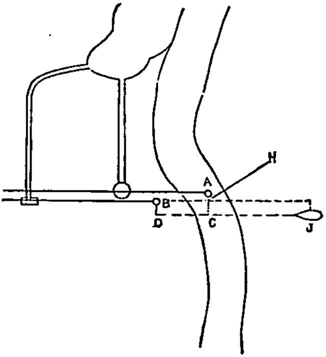
FIG. 3.



Diagrammatic circles of the eye, upon which measurements from the radiographs are made to show location of foreign body. Upper circle, horizontal section; lower circle, vertical section of eyeball. Patient of Dr. Wm. Thomson.

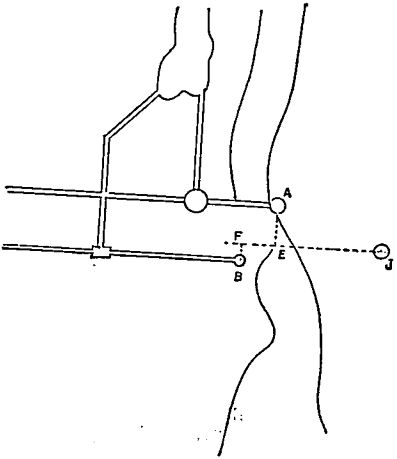
two balls of the apparatus. These measurements are indicated on the circle representing the vertical section of the eye, and a line is drawn through the points. At some point along this line is situated the foreign body. From the second negative, made with the tube below the plane of the two indicators, the measurement is taken of the distance the shadow of the foreign body is above or below the centre indicator, and this point is indicated on the first circle. The same measurements are made for the external indicator. Where a line drawn through these

FIG. 4.



Outline drawing of radiograph made with tube nearly horizontal with plane of indicators.

FIG. 5.



Outline drawing of radiograph made with tube below horizontal plane of the two indicators.

two points crosses the line of measurements made from the first plate is the situation of the foreign body as respects its horizontal and vertical position in the eyeball.

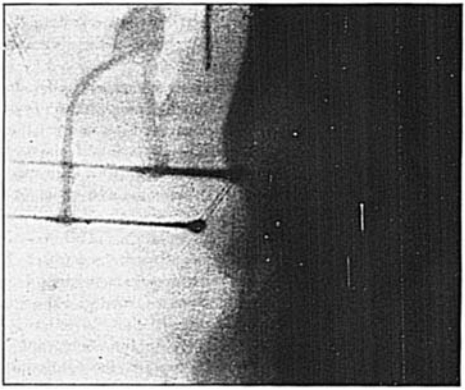
To determine the distance of the foreign body behind the apex of the cornea, one of the negatives is taken and a measurement made of the distance the shadow of the centre ball is posterior to that of the external ball. The distance is entered directly above the external ball on the diagram representing the horizontal section of the eye. From this point a line is drawn through the ball of the centre indicator, which indicates the direction of the rays from the tube when the exposure was made. Taking the plate again, we measure the distance that the shadow of the foreign body is back of that of the external indicator. This distance is marked perpendicularly to the spot representing the ball of the external indicator on the diagram, and a line is drawn parallel to the direction of the rays from the tube. Where this line cuts a line perpendicular to the position of the foreign body shown on the vertical section of the eyeball is the distance the foreign body is behind the anterior portion of the cornea. In cases where the foreign body is in the orbit and outside the eyeball, its location will be indicated by the crossing of the lines beyond the diagrammatic circles.

The first case upon which I employed this method was a young man, twenty years of age, a machinist by occupation. Six months prior to coming to Wills Eye Hospital a piece of steel struck him in the left eye. Dr. William Thomson referred the case to me to determine the presence of a foreign body and its probable location. Examination in April, 1897, showed a scar in the sclera 3 mm. from the corneal margin on the temporal side, starting from the horizontal plane and extending downward almost vertically about 4 mm. The ophthalmoscope failed to reveal the presence of a foreign body, but showed a cone-shaped mass of new tissue extending through the vitreous, with the apex at the disk. The visual field was lost centrally and to the nasal side, but partially preserved downward and outward.

A number of radiographs were made with the Crookes tube in various positions, and in each of the negatives the shadow cast by a foreign body was plainly visible. The two indicators in each exposure were 12 mm. apart, while the ball of the centre indicator was 4 mm. from the apex of the cornea. The external indicator was inadvertently placed 2 mm. nearer the eyeball than the centre indicator. This difference is allowed for on the diagrams. The exposures averaged four minutes each. Employing the method previously described, the measurements from the negatives indicated the position of the centre of the foreign body to be a point 20 mm. from the centre of the cornea, 5 mm. to the temporal side, and 3 mm. below the horizontal plane. The negatives also gave the probable size of the body to be 4 mm. long, 2.5 mm. wide, and 1 mm. thick.

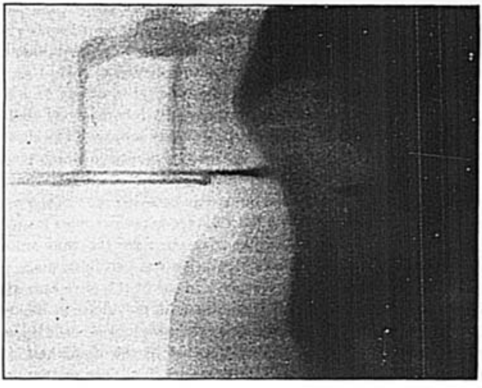
In reporting the case at the Washington meeting of the American Ophthalmological Society, Dr. Thomson stated that, owing to the mass

FIG. 6.



Radiograph made with tube below horizontal plane of indicators. Patient of Dr. Wm. Thomson.

FIG. 7.



Radiograph made with tube nearly horizontal with plane of indicators. Patient of Dr. Wm. Thomson.

of tissue surrounding the body, it was found to be impossible to remove it by the magnet, and that recourse was had to dissection. The body was extracted with some of the cicatricial mass surrounding it from a point in the sclera corresponding to that shown in the diagrams made from the radiographs, with preservation of the eyeball.

The rays were also employed on a patient sent to me by Dr. Jackson, who presented the history of a piece of metal flying into the eye twenty years ago. Examination by Dr. Jackson and by many other gentlemen, at the time the case was shown at a meeting of the Section on Ophthalmology of the College of Physicians, showed a dark mass lying to the temporal side of the disk, about ½ mm. long and ¼ mm. in width, in an area of atrophied choroid and pigment deposit rather smaller than the disk.

Notwithstanding that over a dozen negatives were made of the case at different times with Crookes' tubes running under various degrees of vacuum and placed at various positions, no evidence of a foreign body was shown on a single negative.

The failure of the Röntgen rays to show on the photographic plate the presence of a foreign body in the eye when the ophthalmoscopic examination apparently indicated the existence of a body in the eye, led me to make a number of experiments on the cadaver to determine, if possible:

1. How small a metallic body in the eye could be determined by means of the Röntgen rays.

2. To what extent the bones of the orbit interfered with the passage of the rays.

3. The character of the tube and the vacuum at which it should be operated to give the best results.

4. The best point at which to place the tube.

Experiments were made in the pathological laboratory of Jefferson Medical College on a fresh, well-developed male subject. The shrunken eyeballs were removed, and fresh pigs' eyes employed in which pieces of iron had been inserted. In this way the nearest approach to the ordinary conditions met with in the live subject was secured.

In making the experiments on the cadaver exposures were made with two forms of the Queen focus-tube. In one tube the rays from the concave cathode focussed to a small point on the platinum plate, while in the second tube the focus was larger. In one of the pig's eyes a piece of fine wire was passed through the centre of the globe in its antero-posterior diameter. In another pig's eye three pieces of wire, about one and one-half inches long, were inserted in the nasal half of the pig's eyes, entering at the corneoscleral margin and passing through the ball to the retina. The wires were respectively $\frac{9}{10}$, $\frac{1}{2}$, and $\frac{3}{10}$ mm. in diameter. The largest piece was partially cut through at intervals of

1 mm. In a third pig's eye pieces of iron were inserted in the ball, each about 1 mm. long, and varying in thickness from $\frac{3}{10}$ to 1 mm. The bodies were inserted in the eye at the nasal side. A number of exposures were made with each tube, several at an angle of fifteen degrees, with a vertical plane passing through the two eyes, and a number at an angle of about forty degrees in front of this plane.

These experiments seemed to leave no doubt as to the great superiority of the small focus-point tube as compared with that of large focus. The shadow of even the finest wire is distinctly shown on the negatives made with the former, while in those made with the latter the shadow of the wire is blurred and indistinct. This is in harmony with the well-known fact that the distinctness of the shadow of an object some distance from a plane surface depends upon the size of the source of light, and where the point of illumination is large, as compared with the size of the object, the shadow cast may be indistinct or even imperceptible.

The negatives also show to what small degree the bones of the orbit obstruct the rays. The thickest portion of the external orbital wall is where the frontal and malar bones join, forming the external angle of the orbit. In the deeper portion of the orbital wall the bones are relatively thin. Notwithstanding the difference in the thickness of the bones, the shadows cast by the steel wires are perfectly distinct throughout their entire length. In making radiographs of the eye the best results are secured when the tube is run at high vacuum, so that there shall be great penetration of the ball and the muscular and bony structures. In this way the shadow of the denser metallic body is more clearly shown upon the plate.

In the experiment with the small bodies in the eye the superiority of the small-point focus-tube for eye-work was again shown. The exposure made with the large-point focus-tube failed to show any shadows on the plates of the bodies in the eye, while in the negatives made with the small-point focus-tube each of the five foreign bodies can be clearly seen. In dealing with the live subject the possible slight movement of the head during exposure is a factor of importance.

The position of the tube appears to make very little difference in the results. The negatives made with the tube at an angle of fifteen degrees with the vertical plane passing through the apex of each cornea give as clear shadows of the test objects as when the tube is situated further to the front.

In my experiments I have used several makes of Crookes' tubes, although the majority of the exposures were made with the Queen self-regulating tube. In this tube, by an ingenious arrangement of a shunt circuit, the current passes around the tube when the vacuum becomes too high, heating up an auxiliary bulb of potassium hydrate and bringing down the vacuum. The gap in the shunt circuit may be adjusted to any desired vacuum, and the tube then runs automatically, irrespective of the length of exposure. The time of exposure was varied from two to six minutes, four minutes appearing to give perfectly satisfactory results, although in one instance an exposure of thirty-five seconds gave a negative of excellent detail.

Since the first employment of the above method of determining the precise location of foreign bodies in the eyeball or orbit, numerous opportunities have arisen of verifying the correctness of the findings by subsequent operation. The value of the x-rays in traumatism in the region of the eyeball is shown by the following case, reported by Dr. H. F. Hansell:[1]

> H. L., while pounding sheet steel on January 22, 1898, was struck in the left eye by a piece of the metal. He noticed an escape of fluid from the eye and immediate blindness without much pain. Examination at that time showed a linear incision 3 mm. in extent to the nasal side of the vertical diameter of the cornea, and the anterior chamber filled about one-fifth of its capacity with blood. Under cold applications the blood in the anterior chamber cleared up, and a small ragged opening could be distinctly made out in the periphery of the iris opposite the corneal cut.
>
> Several radiographs were made, the plates recording the shadows of *two metal bodies.* One was located in the posterior chamber immediately under and to the nasal side of the lower end of the vertical diameter of the lens, and the other just anterior to the external orbital angle and very close to it in the soft tissues of the upper lid. The body in the eyeball was successfully extracted by the magnet at the point indicated by the radiographs, with the preservation of the eyeball.

A unique feature of this case was the discovery by the x-rays of the presence of a second piece of metal in the vicinity of the eyeball. The finding was confirmed by passing the magnet point over the part of the lid indicated by the radiographs to contain the body, the skin being raised fully one-quarter inch, showing conclusively the presence of a metal body in the tissues beneath this spot. The patient could not account for the presence of the metal body so near the eye. It certainly did not enter the lid at the time of the injury that destroyed sight.

In the following case reported by Dr. Louis F. Love,[2] the foreign body was removed after one unsuccessful attempt from the location indicated by the radiographs:

> N. C., while engaged in chipping a rivet-head, was struck in the left eye with a fragment of the metal. The upper lid was cut through, the conjunctivæ œdematous, the sclera and cornea incised, vitreous and iris in the wound, the aqueous turbid, and the ciliary region tender on pressure. The vision equalled faint light perception, and all fundus reflex was lost. A series of radiographs located the body in the upper portion

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[1] Section on Ophthalmology, College of Physicians of Philadelphia, March 15, 1898.

[2] Ibid., April 19, 1898.

of the ball just back of the equator. An attempt was made to extract the body by inserting the tip of the Hirschberg magnet through the enlarged wound of entrance, but was unsuccessful, the battery power employed being insufficient to move the body from the inflammatory exudation that existed. A large amount of bloody serum poured from the globe during the operation, so that the ball almost collapsed. Several days afterward the globe regained its shape, and additional radiographs were taken, which showed that the position of the body was the same as when the first negatives were made. The body was then removed by the magnet through an opening made at the equator just under the indicated location. The patient experienced little pain, and the wound healed readily, leaving the globe in fairly good condition.

The value of early operation in cases of foreign bodies in the eyeball, before inflammatory exudate has formed about the metal, is illustrated in the following case, reported by Dr. G. E. de Schweinitz:[1]

A. G., in loosening a piece of work in a lathe by repeated blows of a hammer, was struck in the left eye by a fragment of steel. The metal penetrated near the centre of the cornea, passed through the lens, and rendered the media so opaque that ophthalmoscopic examination was impossible; indeed, the lens in the ten hours that elapsed from the time of injury had become cataractous. A series of radiographs made the day following the injury indicated a piece of metal about 3 mm. long and 1 mm. wide situated 2 mm. below the horizontal plane of the globe, nearly 2 mm. to the nasal side and 23 mm. back of the centre of the cornea. The next day an incision was made through the sclera just below the lower margin of the external rectus, and the broad, flat extension point of a Hirschberg magnet introduced a distance of 15 mm., so as to bring it as nearly as could be calculated over the position of the macula. On withdrawing the magnet point a piece of steel, of triangular shape, of the size indicated, and weighing one-seventh of a grain, was found adhering to it. Three weeks after the operation the eye was still much injected and the tension raised owing to the swelling of the lens. The light-perception, however, is good in all portions of the field, although the condition of the eye indicates later enucleation as probable.

No better example of the value of the Röntgen rays in ophthalmic surgery could be found than is furnished by this case. The media were clouded, and there was no other means of determining whether the metal was imbedded in the opaque lens, was lodged in the vitreous chamber, or had passed completely though the eyeball into the orbit. The radiographs not only indicated the portion of the eyeball in which the body was lodged, but rendered possible a determination of its exact location.

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[1] Ibid.